Effect of Process Parameters on the High Speed Seam Weldability of Tin Coated Steels for the Small Containers

K. C. Kim and M. Y. Lee

Abstract

High speed seam weldability of tin coated steels was investigated. Welding was performed by the laboratory wire seam welder that was equipped with process monitoring system. Test results showed that increase in applied current and pressure reduced the total resistance across the welding electrodes. Lower and upper limits of welding current increased as the sheet thickness increased, while the acceptable welding condition range decreased. However, extremely low electrode pressure produced unstable welding condition range. The results also demonstrated that slower welding speeds widened the optimum welding heat input range.

Key Words : Coated steel, Resistance welding, Seam welding

1. Introduction

In the small container manufacturing line, overlap seam welding process used to be one of the most important joining methods for high productivity and good quality[1-3]. In this sense, wire seam welding is a suitable process since the method uses consumable copper wire electrode as current and pressure supply.

The wire seam welding process has some advantages over conventional resistance welding; no contamination caused by alloying effect between electrode and coating materials on the base plate, extremely high processing speed which is desirable in the practical line without dressing of electrodes, and good and stable weld quality.

Small containers including the beverage cans are made by tin coated very thin gage steels. The thickness of these materials ranges from 0.2mm to 0.4mm or so, and they contain extra low alloy elements. It is not practical to join the steels by conventional resistance welding technique because volume of the base metal to be welded is too small to produce sufficient heat by the welding current via wheel electrodes. In the welding of these kinds of materials, the weldability varies with base metal thickness and tin coating layer.

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In this paper, an effect of the material thickness and tin coating on the weldability of thin steels for small cans or containers were investigated to optimize the welding process.

2. Materials and experimental procedure

2.1. Test materials

As shown in Table 1, the test materials were low and medium strength steels. The range of carbon equivalent, C_{eq} was 0.030 to 0.111. There were three groups of test steels corresponding to the thickness; group A(0.35mm in thickness) that was the material for the pail cans, group B(0.21mm in thickness) and group C(0.25mm in thickness) that were mainly used to make medium and small beverage cans. Cold rolled plates were heat treated in the continuous annealing furnace, and tin coating was performed in the electrolytic plating line.

Table 1 Physical properties of test materials

	Carbon equivalent (%)	Tensile strength (MPa)	Coating weight (g/m²)	Thickness (mm)
A-1	0.030	328	1.1/1.1	0.35
A-2	0.032	356	2.8/5.6	
B-1	0.071	418	2.8/11.2	0.21
B-2	0.111	443	2.8/2.8	
C-1	0.073	439	2.8/2.8	0.25
C-2	0.076	403	2.8/5.6	

2.2. Welding and process monitoring

Welding was performed by the test welding machine that was equipped with a phase control system of line frequency of 60Hz. Maximum welding speed of the test machine was 15m/min. Pure copper wire was used as a welding electrode and the diameter of the electrode was 1.5mm.

The size of test samples was 150mm wide and 400mm long. In the welding of the specimens that had different coating weight on each side, caution was given that the contact faces should have same coating condition.

Welding process was monitored by computer-based process monitoring system that was equipped with the coreless low impedance current sensor, frequency to voltage converter and high speed analog to digital converter. Table 2 shows the welding conditions.

Table 2 Test welding conditions

Welding current range	0.5~4.0kA
Electrode pressure	127~250N
Welding speed	7~16m/min
Overlap	3.0mm

3. Results and discussion

3.1. Effect of the welding conditions on a contact resistance

According to the previous studies[1-4], the resistance weldability of the thin gage steels got worse if the contact resistance between test sample surfaces increased. The phenomenon could be explained by the spattering characteristics during welding. When the applied welding current is high, it is easy to heat up the contact bridges, which results in forming the superheated melt at the very limited region. The melt would splash out from the interface forming so called spatter.

Fig. 1 shows the relationship between welding conditions and total resistance (the resistance across the electrodes which is calculated from the welding current and voltage drop between electrodes). In the figure, it is clear that total resistance decreases with an increase of welding current. However, the effect of welding pressure is greater than that of the welding current. At the lower electrode pressures of 147N and 216N, the line slopes are

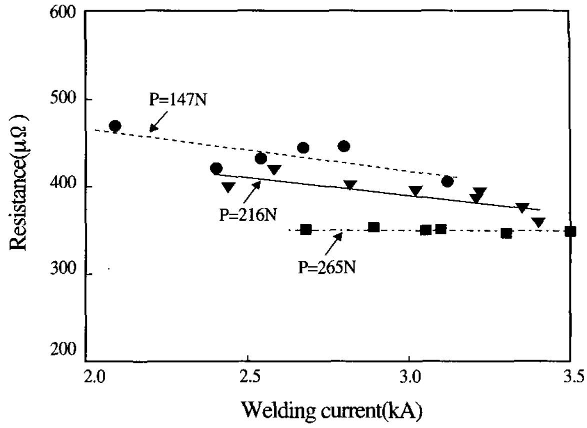

Fig. 1 Relationship of welding current, total resistance and electrode pressure

relatively steep. At the welding pressure of 265N, however, the resistance shows around 350μΩ and is almost constant.

Lower electrode pressure produces higher contact resistance, and it in turn produces higher joule heat at the given area on the test sample surface. Extremely high temperature at the small volume of the sample produces spattering which results in reduction of the optimum condition range. On the other hand, higher electrode pressure can keep the resistance low and stable. Major parameters to determine the contact resistance of the given material are surface roughness and oxide product that lowers the conductivity. If the resistance is low and stable at the given surface, it increases the upper limit of the welding current without spattering and consequently widens the optimum welding condition range.

However, some of the researchers insist that the electrode pressure is low and is applied to very limited area during the welding so that the contamination or coating material will be removed at the early stage of the process.

3.2 Effect of material thickness

It is normal in the small containers manufacturing line that base metal thickness varies with the usage of the final products. The base metal thickness change actually means that the welding conditions are necessarily changed since heat production and thermal conduction condition should be different from a sheet to another. Therefore, it is worthy to know the trend how the welding behavior changes with the material thickness.

Fig. 2 shows the relationship between the plate thickness and optimum welding current. In this figure, steels A-1, B-2 and C-1 had thicker coating layer than that of the steels A-2, B-1 and C-2. As the plate thickness increases, both lower and upper limits of welding currents also increase. However, acceptable welding condition range decreases with an increase of thickness and/or welding current limits.

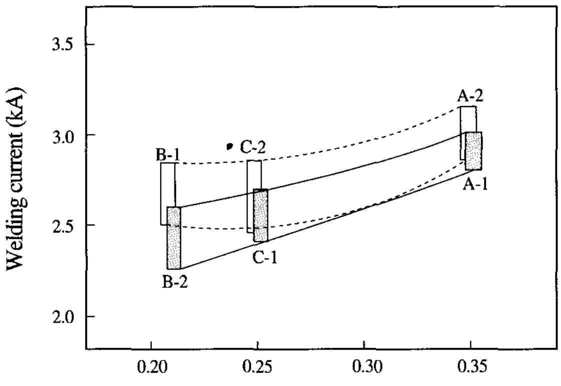

Fig. 2 Relationship between sheet thickness and optimum welding current range

3.3. Effect of coating layer

Previous study shows that carbon content in the base metal is another factor influencing the weldability. If base metal contains 0.06~0.10wt.% of carbon, for example, the weld would be hardened and spattering was observed in the welding process. However, the weldability of zinc coated steels is mainly affected by the coating layer. The layer would easily make Cu-Zn alloy contaminating the welding electrode[6-8]. In the wire seam welding process, the electrode contamination by alloying is not the problem since consumable wire electrode is used.

Fig. 3 is the test result showing the effects of tin coating layer and material thickness on the size of the acceptable welding current range, Δi. According to the figure, the Δi decreases as the plate thickness increases. Approximately, the decreasing slope of Δi is remarkable in the light coating steel. However, the Δi of thin steel is wider than that of thicker steel regardless of the amount of the coating conditions.

A study reported that the Δi could not be found in welding of a sheets with tin coating weight of 0.55g/m^2 or

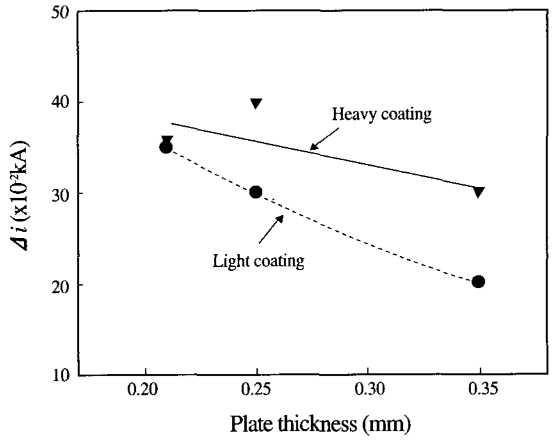

Fig. 3 Effects of sheet thickness and tin coating condition on the weldability

more. However, another study urged that the Δi of steel with the coating weight of 0.5g/m^2 was 0.4kA and that of 2.8g/m^2 was 0.9kA, respectively. There have been some discrepancies among studies, which will be one of the future tasks to be cleared.

Fig. 4 shows the effect of coating amount on the weld strength. In the figure, it is found that acceptable welding heat input of steel B-2 is 8.5 J/mm. However, the limit of steel B-1 is 9.3J/mm, which means that the steel B-2 shows better weldability.

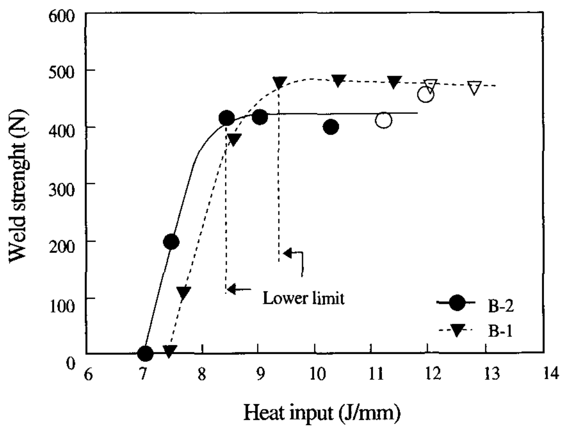

Fig. 4 Effect of coating weight on the tensile-shear strength

Correlation between optimum welding range, ΔQ and welding pressure is shown in Fig. 5. From this results, steel C-2 has better weldability than steel C-1 since the steel C-2 indicates wider ΔQ values over the test range.

The surface roughness of steel C-1 was slightly high and it might be sensitive to the spattering at the lower electrode pressure. When the welding pressure is

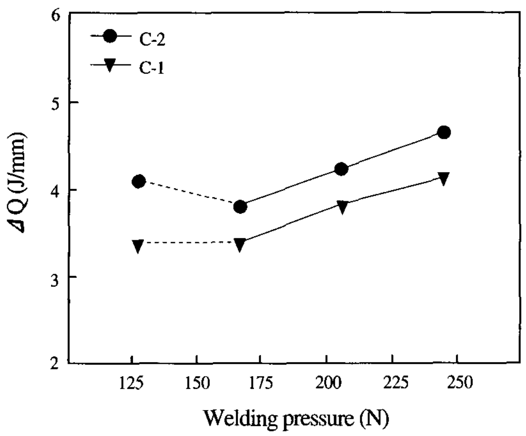

Fig. 5 Effect of welding pressure on the optimum welding heat input range

controlled at low level, the steels have wider ΔQ values shown as dotted line in the figure but unstable.

Fig. 6 is another test results showing the effects of welding parameter and coating layer on the ΔQ value. As the welding speed increases, the ΔQ value decreases rapidly. Higher welding speed means that the specimen has less time to be heated.

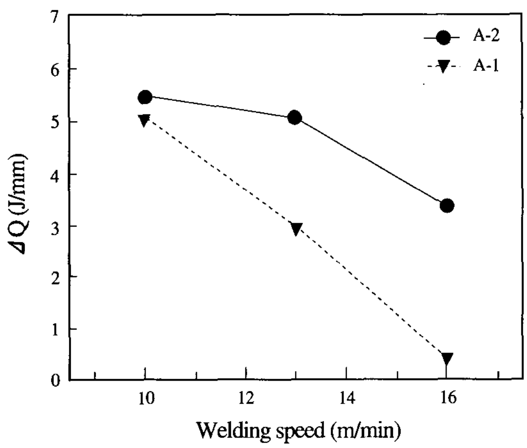

Fig. 6 Effects of welding speed and coating weight on ΔQ value

Thus, higher welding speed reduces both the total amount of heat per unit cross-sectional area and input energy at the same time. Again, this effect could increase the spattering current and consequently could widen the upper limit of welding current. Test results of the steel A-1 which has thicker coating layer than A-2 shows steeper reduction of the ΔQ in accordance with the increase of the welding speed.

4. Conclusion

Based on the calculation from the monitored results, it was clear that an increase of the welding current resulted in decrease of total resistance across the current consuming circuit. However, the effect of welding pressure on the resistance was greater than that of the welding current. Low and stable resistance was displayed at the higher electrode pressure.

As the base metal thickness increased, both lower and upper limits of welding current increased, which indicated that higher energy had to be provided to form a sufficient weld. In this case, the acceptable welding condition range decreased.

At the higher welding speeds, the acceptable welding range decreased rapidly since higher welding speed allow less time to heat the specimen. The results also demonstrated that slower welding speed was recommended to expand the acceptable welding range.

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